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CONTRACT REPORT NO. 1SQ 85-00300

COMPARATIVE EXAMINATION OF FLY ASH AND MAGNETITE HEAVY MEDIA FOR COAL BENEFICIATION (UP-R-230)

Final Report To

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DSS File Number 15SQ.23440-5-9228

MICROMEDIA

86 pp

JOB NO: 05000223
REPORT NO: AS/87/14
DATE: October 20, 1986
KTF/mb/AS3

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Project Leader

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1.0 ABSTRACT

The work described in this report shows that a magnetic concentrate of S.G. 3.9 can be produced from the high iron fly ash of New Brunswick Minto coal and that it has media properties similar to that for natural magnetite. It is less abrasive, stays in suspension longer and possesses the same pH in slurry as magnetite. Solids loading and viscosity are higher. Bench scale tests with coal are required to further demonstrate that the fly ash can be used for the heavy media instead of magnetite.

RESUME

L'ouvrage décrit dans ce rapport démontre qu'un concentré magnétique avec un poids spécifique de 3.9 peut être produit en utilisant du charbon de Minto, Nouveau Brunswick. Ce charbon est composé de cendre flottante avec haute concentration de fer et possède des propriétés d'agents intermédiaires semblable au magnétite naturelle. Ce produit est moin abrasif, demeure en suspension plus longtemps et possède la même teneur pH en schlamm que la magnétite. De plus, la capacité de chargement en solides et la viscosité sont plus élevés. Des essaies à échelle réduite avec du charbon sont nécéssaires pour démontrer davantage que la cendre flottante peut être utilisée comme agent intermédiaire lourd au lieu du magnétite.

2.0 BACKGROUND

The fly ash produced from the combustion of New Brunswick Minto Coal is high in Fe_2O_3 (50%) which makes it a unique fly ash from which to concentrate a dense, magnetic fraction. By comparison, most other coal fly ashes contain roughly 10% iron rendering them unacceptable for processing of this type.

Such magnetic concentrates are thought to be a viable substitute for the commercial magnetite currently used for the dense media in coal beneficiation plants. There is presently a demand in the Atlantic region for magnetite at the Victoria Junction wash plant of Devco in Sydney, Nova Scotia. In 1983 the plant purchased 7000 tonnes of this product at $100 per tonne. If it were demonstrated that a local fly ash concentrate (FAC) could clean coal as effectively as magnetite, with a possible cost reduction, it is probable that Devco would be interested.

The New Brunswick Electric Power Commission is currently evaluating the possibility of using a heavy media concentrate from its fly ash to beneficiate Minto coal*. If this were to prove successful the benefits would be numerous: an upgrading of the coal quality, partial alleviation of the fly ash disposal problem, a potential market (Devco) for any capacity greater than that needed to meet in-house demands and the creation of employment. There could then be further benefit in using the fly ash, now devoid of the bulk of its iron, as a pozzolan for concrete admixtures. At present the high iron content precludes such use. Again this would aid in disposal, satisfy potential market demand and produce jobs.

*A consultant, B. Roberts of Bedford, N.S., has had a magnetic concentrate made from Minto fly ash in the U.S. He claims that it has an S.G. of more than 3.9 and that it is excellent for heavy media. None was available for inclusion in this test program.

Previous work undertaken at RPC ("Preparation of a High Specific Gravity Concentrate from the Iron-Rich Fly Ash of the Minto Coal, N.B.") has shown the feasibility of using wet magnetic separation to concentrate the magnetic fraction of this fly ash.

3.0 INTRODUCTION

The purpose of this work was to produce a high density magnetic fraction from the fly ash of Minto coal and then to compare the rheology of various media prepared from this material with similar media prepared from a commercial magnetite. The magnetite obtained is currently in use at the Devco Victoria Junction Wash Plant in Sydney, Nova Scotia. The DSS Work Statement is given in Appendix A.

Preliminary work on the preparation of a magnetic concentrate was carried out in March 1986 (Appendix B). The results of that work had shown that a magnetic concentrate of S.G. 3.9 could be obtained at yields of 20 percent. It also showed that the S.G. increased with a decrease in grain size, thus the decision was taken to reduce the fly ash to -325 mesh (44 microns) for the magnetic concentration process.

4.0 PREPARATION/PROCESSING OF HIGH SPECIFIC GRAVITY MATERIALS

4.1 Preparation of a Heavy Magnetic Fraction From Fly Ash

Prior to processing, a sample of the raw fly ash was submitted for chemical and mineralogical analysis (Table 1). A photomicrograph taken at this time shows the physical structure of this material; numerous coarse grains, some rounded grains (cenospheres) and clumps of magnetic material (Plate 1).

Sieve analysis, also performed at this time gave the results shown in Table 2. All fly ash for separation of the magnetic fraction was milled to -325 mesh.

Table: 1

Chemical and Mineralogical Analysis

Analysis: Weight %

	Fly Ash Concentrate	Magnetite
SiO_2	4.64	3.66
Al_2O_3	6.36	2.80
Fe_2O_3	74.6	80.4 (as Fe_3O_4)
CaO	1.32	0.1
MgO	0.26	0.47
TiO_2	0.29	4.9
Na_2O	0.40	0.09
K_2O	0.63	0.13
P_2O_5	0.64	<0.1
Total S	0.10	0.30
L.O.I.	--	7.68

Trace Elements (ppm) Li 8, Be <1, Rb <8, Sr 60, Nb 9, Ba <1, Ta <8, V 128, Cr 5, Co 18, Ni 12. Cu 3, Zn 16, As 18, Se <5, Mo <1, Ag <0.5, Cd <1, Sn <10, Sb <5, Te <10, Wo <10, Pb 18, Bi <2, V <10.

X-ray Diffraction Examination

Sample	Constituents Identified
Fly Ash Conc.	Magnetite, hematite, some quartz
Magnetite	Magnetite, trace hematite

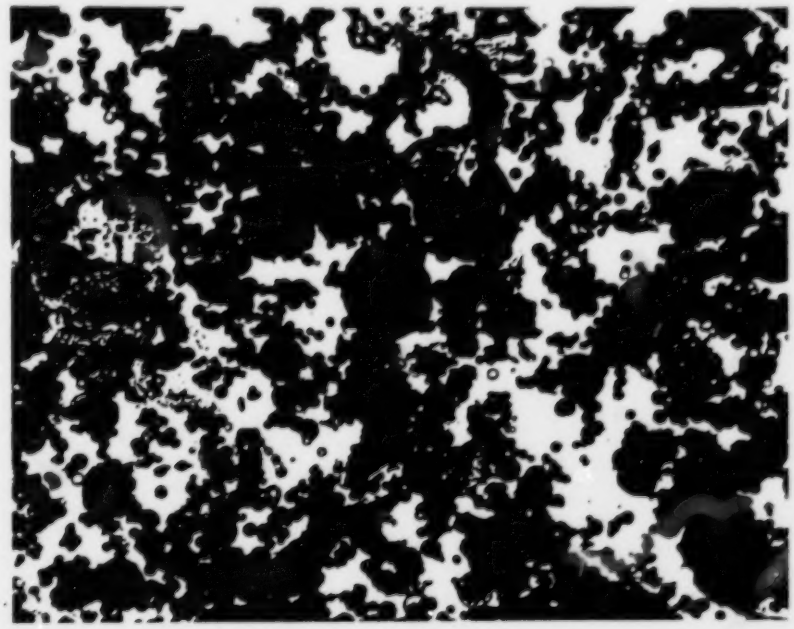


Plate 1 As Received Fly Ash
(73% -325 mesh)
1 cm = 44 microns

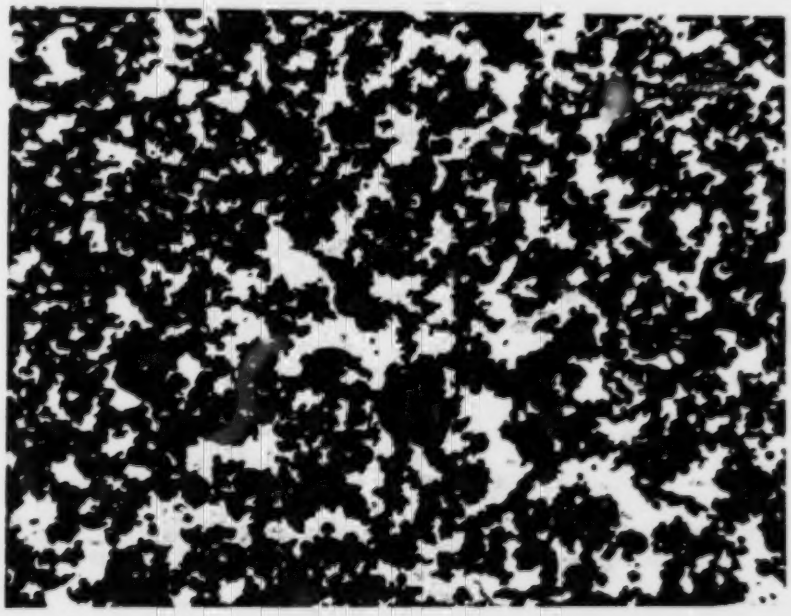


Plate 2 Fly Ash Ball Milled to Reduce Grain Size
(98% -325 mesh)
1 cm = 44 microns

As fly ash used commercially is 90 percent -270 mesh the ash was ball-milled for 6 hours to reduce the grain size, resulting in the sieve analysis shown in Table 2. Plate 2, a photomicrograph of the milled fly ash, indicates visually the change in composition; the lack of large particles and the survival of small cenospheres in the material.

The milled fly ash was mixed with water and passed through a Carpco wet magnetic separator. This unit consists of a 4" square aluminum funnel, partially filled with 1/2" iron balls and situated between the poles of an electromagnet. The current to the coils and hence the magnetic field strength can be varied thereby optimizing the separation. After several trials it was found that a maximum setting produced the best results.

Magnetically susceptible material clung to the iron balls which were continuously washed with water to remove the non-magnetic particles. Once the wash water ran clear the current was shut off and the magnetic material collected. The process was repeated once more with this concentrate in order to attain the highest specific gravity possible. Additional runs with small portions of the material did not increase the S.G. and only contributed to the loss of material in the system, i.e. a lower yield. The average S.G. of the magnetite concentrate produced was 3.88. Earlier work had reached S.G. 3.97 but in using the Carpco separator for large batch treatment it was difficult to obtain higher values. No efforts were made to optimize yield and to obtain good recovery.

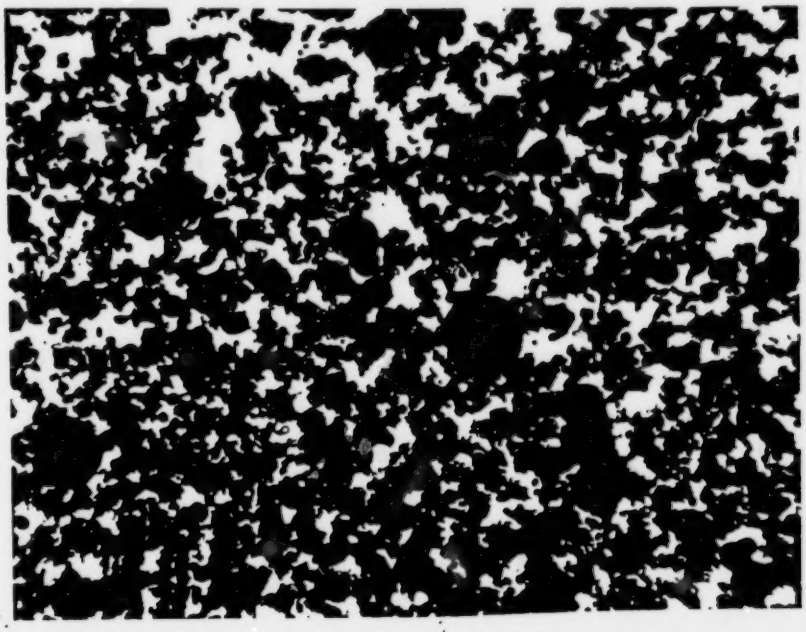


Plate 3 Magnetite from Heavy Media

1 cm = 44 microns

4.2 Processing of the Magnetite

The magnetite from the Victoria Junction Wash Plant was received in slurried form and was first dried. A sample was taken, the lumps broken up with a mortar and pestle and the material sieved (Table 2). The photomicrograph in Plate 3 seems to bear out this analysis; note the apparent coarse-grained nature of the magnetite with some particles $\geq$ 50 microns.

Table 2

Fly Ash and Magnetite Sieve Analyses

Mesh	+100	100-270	270-325	-325
Microns	+149	149-53	53-44	-44
As Received	2.25	18.18	6.23	73.34
Ball Milled		0.28	1.44	98.28
Mag. Conc.		0.44	1.56	98.00
Magnetite		72.92	17.86	9.22

5.0 TEST PROGRAM

5.1 Density

The densities of the FAC and the magnetite were determined using a standard Le Chatelier Flask and the method outlined in ASTM C188-78, "Standard Test Method for Density of Hydraulic Cement". In this report the terms "density" and "specific gravity" are synonomous.

5.2 Size Distribution

The grain size distributions of the 2 samples (FAC and Magnetite) were determined by automated image analysis (AIA). The materials were first demagnetized, to prevent erroneous counts caused by clumping, and then mounted in oil. The slides were imaged by a TV camera interfaced with an optical microscope. This image was fed to a computer which recorded the grain size of each particle. The movement of the microscope stage was also computer controlled which provided for the automatic selection of several fields of view. The number of fields of view processed (usually 100) can be set by the operator resulting in the measurement of several thousand grains. The collected data was then analyzed by the computer and displayed in histogram and tabular forms.

5.3 Solid Loading/Specific Gravity

The volumetric concentration of a solid needed to produce a slurry of a particular specific gravity was calculated as follows:

$$X = \frac{P - P2}{P1 - P2} \times 100$$

where X = volumetric concentration (%)
P = SG of media required
P1 = SG of concentrate
P2 = SG of water

5.4 Media Stability

Stabilities of various solid-liquid suspensions were determined by investigating their sedimentation rates. Media of specific gravities 1.3, 1.4, 1.5, 1.6 and 1.7 were prepared using FAC and magnetite.

Each slurry was prepared in a 500 ml graduated cylinder using the appropriate quantities of water and concentrate. The total mixture volume was 450 ml.

The cylinder was stoppered and then inverted several times in order to ensure thorough mixing. It was placed on a flat, level bench and a stop watch activated. The height of the solid-liquid interface was recorded at 10 second intervals for the first minute, at 30 second intervals for the following 4 minutes and finally at 1 minute intervals for the last 10 minutes. This yielded 24 readings over a 15 minute period (generally) after which settling was virtually complete. Each test was repeated once more and the results averaged.

5.5 Viscosity

Viscosity measurements were carried out using both a Brookfield Model LVF viscometer and a Ferranti Model VM viscometer. Although the results obtained by each are not comparable they serve to define relative viscosities and viscosity trends.

The Brookfield viscometer measures viscosity by determining the force required to rotate a spindle in a fluid. A motor and gear transmission (at the top of the instrument) drive a dial which is connected to one end of a calibrated spring. The other end of the spring is attached to a pointer. The dial in turn drives a pivot shaft through the spring. The model LVF is a 4 speed unit; 6, 12, 30 and 60 rpm. A UL adapter was used to extend the minimum range of measurement from 0-100 mPa·S to 0-10 mPa·S.

This was needed in some cases to improve the accuracy when working with media of low SG (1.3) and at low speeds (6 or 12 rpm). The adapter consists of a large cylindrical spindle rotated inside the walls of a concentric tube. Measurements were carried out at all four speeds.

The Ferranti viscometer is of the Couette Coaxial cylinder design. The inner cylinder is suspended on jewelled bearings while the outer cylinder is driven at constant speed by a high torque synchronous motor. The inner cylinder is free to rotate against a calibrated spring attached to a pointer showing angular deflection. Inner cylinders are interchangeable and selected to cover the anticipated viscosity range. A 3 speed gear box is provided so that the rpm of the outer cylinder may be varied. As with the previous instrument, this is done in order to examine viscosity change trends. The model used here was equipped with VL (low viscosity) cylinders.

5.6 Particle Abrasion/Attrition/Corrosion

These three properties of the heavy media were examined simultaneously by setting up an abrasion test system. Media of S.G. 1.3, 1.5 and 1.7 were prepared from FAC and magnetite and placed in large buckets. The slurry pH's were recorded and an aluminum test coupon attached to the inside wall of each bucket, below the surface of the liquid and with its face inclined 30^{o*} to the direction of fluid flow. The buckets were covered to prevent evaporation and the shaft of an electric stirrer inserted through a hole in the top of each.

The stirrers were run at 350 rpm which, with the propeller design used, imparted an average velocity to the slurry (over the face of the coupon) of 3.5 ft/sec.

*It is noted in the literature that this inclination (20^{o}-30^{o}) produces maximum abrasion in a ductile material.

The test coupons were all roughly 59 mm in height, 50 mm in width and 3.2 mm in thickness. Each was weighed prior to immersion in the media and then at 12 hour intervals thereafter for the 72 hour duration of the test. Slurry pH's were also recorded at these times.

It was noticed that in several abrasion tests, particularly at high media S.G., there was a buildup of solids on both the front and rear surfaces of the aluminum. Initially it seemed that pitting was occurring which increased the rate at which the particles adhered to the metal. Later microscopic examination proved that this was in fact so.

Before each weighing the coupons were scrubbed with a stiff bristled brush in an attempt to remove as much of the material as possible. This was not entirely successful and in some cases the coupon weight actually increased.

After 72 hours the 6 slurries were filtered and samples of the remaining solids submitted for analysis of the particle size distribution. Comparison of this data with that obtained from the FAC and magnetite before testing provided information as to the amount and rate of particle attrition encountered.

At the conclusion of testing the FAC abraded coupons were allowed to air dry for several days after which time it was found to be possible to remove much of the surface material by scraping with a plastic spatula. Four hours in an ultrasonic bath loosened a good deal of the embedded particles as well.

Feeling that there would be problems with the results, another FAC abrasion test was performed. The aluminum coupon was first polished to remove any pits or scratches and then placed in a 1.3 S.G. media. Its weight, along with the slurry pH, was recorded initially and then at 24 hour intervals for 7 days.

Prior to each weighing the accumulated surface material was scraped and the coupon placed in the ultrasonic bath for 4 hours.

5.7 Intensity and Retention of Magnetic Properties

The most common method of comparing the magnetic properties of one heavy media material to those of another is to determine the weight percentage of magnetically susceptible particles contained in a sample of each. At best this is a somewhat rough measurement, regardless of the method used, and so it was decided to employ the Carpco wet magnetic separator for this purpose.

Batches of FAC and magnetite were run through the unit and the percent magnetics determined. Samples of the solids remaining from the S.G. 1.5 abrasion tests were then processed similarly and a comparison made between these two data sets.

6.0 RESULTS

6.1 Density

The densities of the FAC and the magnetite were determined as outlined in ASTM C188-78. Four tests were conducted in each case (Table 3).

6.2 Size Distribution

Automated Image Analysis showed that, on average, the FAC and magnetite particle sizes were similar which is at variance with the previous sieve analyses. To summarize this data the minimum, maximum and mean particle sizes are shown for FAC and magnetite (Table 4). Figure 1 shows a histogram of FAC particle absolute frequency while Table 5 provides the size range list. Figure 2 and Table 6 provide the same information for the magnetite.

TABLE 3: FAC and Magnetite Density

Test	1	2	3	4	Average
FAC	3.87	3.87	3.89	3.88	3.88
Magnetite	4.86	4.84	4.86	4.85	4.85

TABLE 4

FAC and Magnetite Particle Size

	FAC	Magnetite
Min. Particle Size (microns)	0.8	0.5
Max. Particle Size (microns)	30.0	29.6
Mean Particle Size (microns)	4.2	2.0
Standard deviation	1.8	2.1

SELECTED DATAGROUP

ID.NR. TR SA EXT.1
FASH 02 00 0

CHANNELGROUP 0

FIGURE 1

Fly Ash Absolute Frequency

FIGURE 2

Magnetite Absolute Frequency

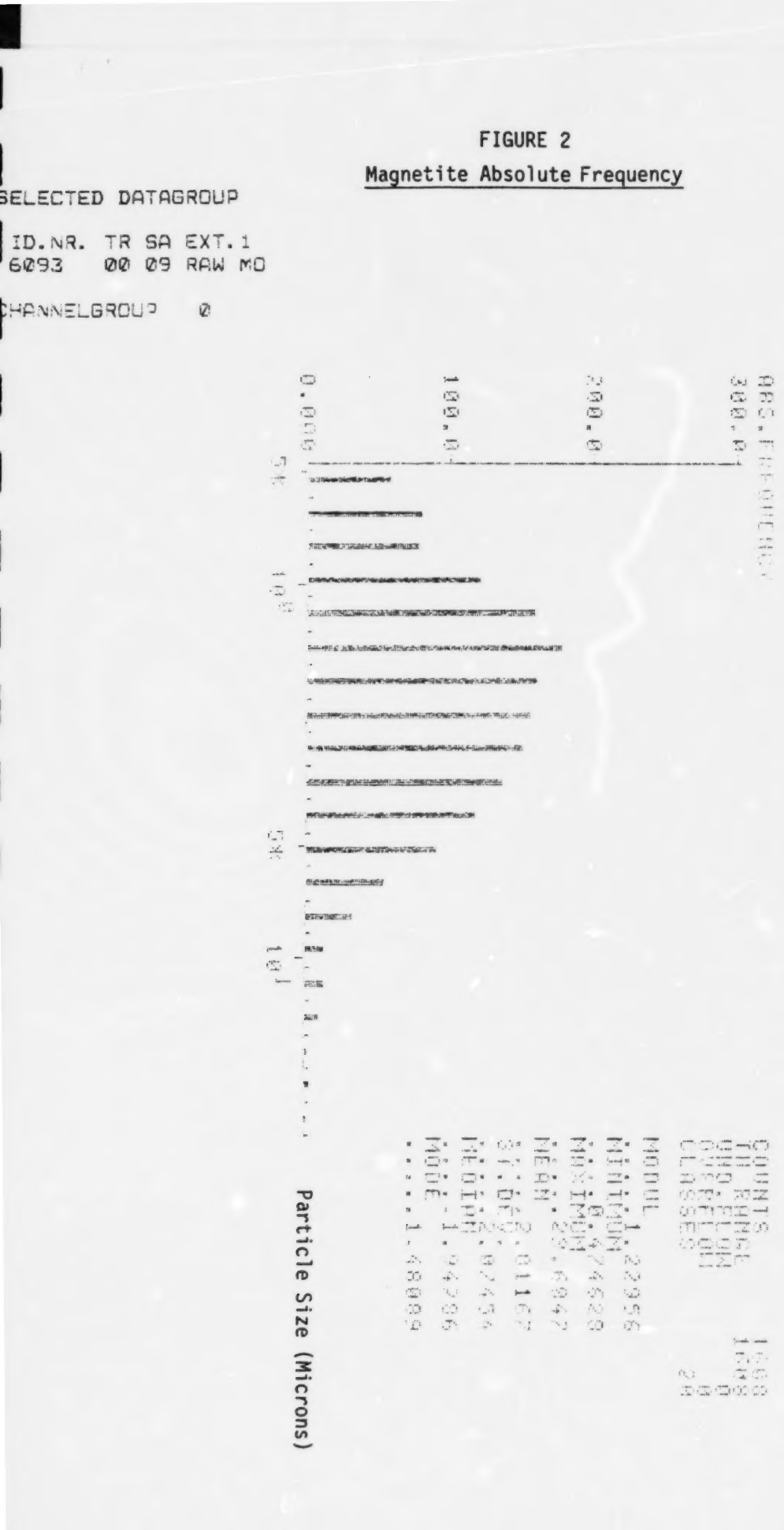


TABLE 5

Fly Ash Concentrate Size Classification List (Microns)

Class	From	To	Frequencies			
			ABS	REL	CUM. ABS	CUM. REL
1	.80000	1.0187	3.	.19%	3.	.19%
2	1.0187	1.2971	15.	.97%	18.	1.16%
3	1.2971	1.6516	43.	2.78%	81.	3.95%
4	1.6516	2.1030	88.	5.69%	149.	9.64%
5	2.1030	2.6777	184.	11.90%	333.	21.54%
6	2.6777	3.4096	261.	16.88%	594.	38.42%
7	3.4096	4.3415	233.	15.07%	827.	53.49%
8	4.3415	5.5281	222.	14.36%	1049.	67.85%
9	5.5281	7.0390	188.	12.16%	1237.	80.01%
10	7.0390	8.9628	164.	10.61%	1401.	90.62%
11	8.9628	11.412	82.	5.30%	1483.	95.92%
12	11.412	14.532	43.	2.78%	1586.	98.71%
13	14.532	18.503	12.	.78%	1538.	99.48%
14	18.503	23.561	3.	.19%	1541.	99.68%
15	23.561	30.000	5.	.32%	1546.	100.00%

TABLE 6

Magnetite Concentrate Size Classification List (Microns)

Class	From	To	Frequencies			
			ABS	REL	CUM. ABS	CUM. REL
1	.47463	.58358	57.	3.54%	57.	3.54%
2	.58358	.71755	80.	4.98%	137.	8.52%
3	.71755	.88228	78.	4.85%	215.	13.37%
4	.88228	1.0848	121.	7.52%	336.	20.90%
5	1.0848	1.3338	158.	9.83%	494.	30.72%
6	1.3338	1.6400	178.	11.07%	672.	41.79%
7	1.6400	2.0165	161.	10,01%	833.	51.80%
8	2.0165	2.4795	155.	9.64%	988.	61.44%
9	2.4795	3.0487	151.	9.39	1139.	70.83%
10	3.0487	3.7485	136.	8.46%	1275.	79.29%
11	3.7485	4.6090	117.	7.28%	1392.	86.57%
12	4.6090	5.6671	91.	5.66%	1483.	92.23%
13	5.6671	6.9680	54.	3.36%	1537.	95.58%
14	6.9680	8.5676	32.	1.99%	1569.	97.57%
15	8.5676	10.534	12.	.75%	1581.	98.68%
16	10.534	12.953	12.	.75%	1593.	99.07%
17	12.953	15.986	9.	.56%	1602.	99.63%
18	15.926	19.582	1.	.06%	1603.	99.69%
19	19.582	24.078	3.	.19%	1506.	99.88%
20	24.078	29.605	2.	.12%	1608.	100.00%

TABLE 7

FAC, Magnetite Volumetric Concentrations

S.G.	FAC Vol. Conc. (%)	Magnetite Vol. Conc. (%)
1.3	10.42	7.79
1.4	13.89	10.39
1.5	17.36	12.99
1.6	20.83	15.58
1.7	24.31	18.18

Note that the actual mixing of media to obtain particular densities was done on a weight basis.

6.3 Solid Loading/Specific Gravity

Given that the SG of the FAC was 3.88 and that of the magnetite was 4.85, the volumetric concentrations over the S.G. range 1.3 to 1.7 are given in Table 7.

6.4 Media Stability

Figures 3 and 4 show plots of the solid/liquid interface heights versus time for FAC and magnetite media respectively. Media S.G. of 1.3-1.7 inclusive were examined and are shown together on a single pair of axes. Raw data may be found in Table 8.

It will be noted that in virtually all cases there is an initial period of linearity associated with each curve which represents constant velocity settling. Ultimately as the bed of solids built up and began to compress, a reduction in the rate of setting occurred, indicated by the decreasing slopes of the curves.

To make comparisons of the relative stabilities of the various heavy media a least squares regression fit was applied to the initial linear portion of the plots and then a second set of graphs prepared of sedimentation rate versus media specific gravity. Figure 5 shows this graphically. It is evident that the magnetite slurries settled much more rapidly than their FAC counterparts of similar S.G. At an S.G. of 1.7 the former settled almost 8 times as quickly. Also on this graph are two other plots; the settling of -325 mesh Pennsylvania Fly Ash Material (FAM) and Reiss-Viking Grade 965 Magnetite vs. Media S.G. This information was obtained from the source listed in the References, Item 5 and is presented for comparative purposes.

FIGURE 3: FAC Media Settling Rates

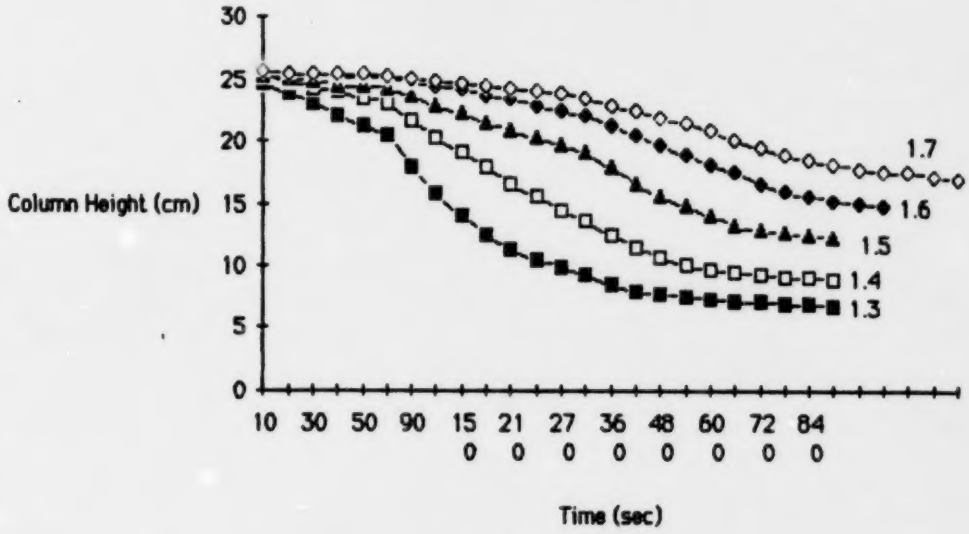


FIGURE 4: Magnetite Media Settling Rates

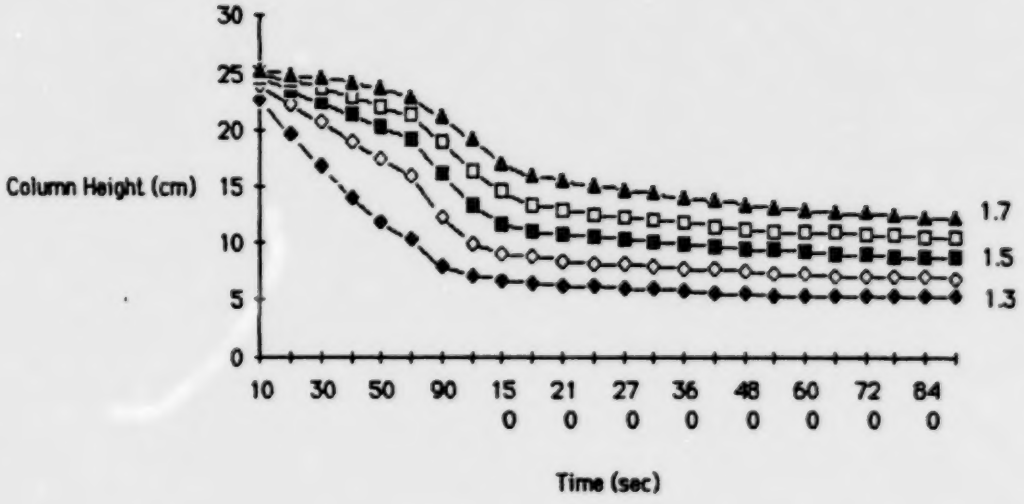


FIGURE 5: Settling Rates of FAC and Magnetite

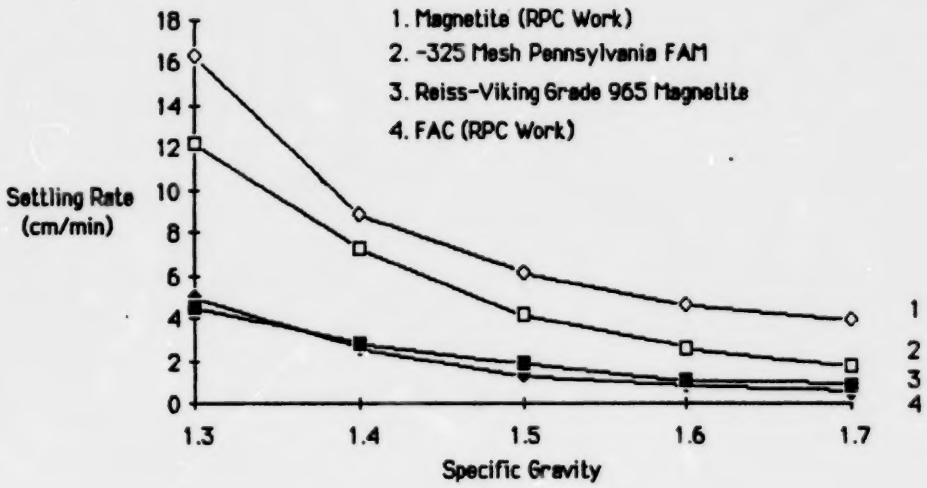


Table 8: Liquid/Solid Interface Height (cm)

Time	FAC					Magnetite				
(sec)	1.3	1.4	1.5	1.6	1.7	1.3	1.4	1.5	1.6	1.7
10	24.6	25.3	25.1	25.5	25.5	22.6	23.8	24.4	24.9	25.2
20	23.7	24.7	24.9	25.4	25.4	19.5	22.2	23.4	24.2	24.8
30	23.0	24.2	24.7	25.3	25.3	16.7	20.6	22.3	23.6	24.5
40	22.1	23.9	24.4	25.2	25.3	14.0	18.9	21.2	22.8	24.1
50	21.3	23.3	24.3	25.1	25.3	11.8	17.3	20.1	22.0	23.6
60	20.4	23.0	24.2	25.0	25.2	10.2	15.8	19.1	21.3	22.8
90	17.9	21.6	23.6	24.7	25.0	7.8	12.1	16.0	18.9	21.0
120	15.7	20.3	22.8	24.3	24.8	7.0	9.8	13.3	16.4	19.0
150	13.9	19.1	22.2	24.1	24.6	6.6	9.0	11.6	14.5	17.0
180	12.4	17.9	21.4	23.6	24.3	6.4	8.7	11.0	13.2	15.8
210	11.2	16.6	20.9	23.3	24.1	6.2	8.4	10.7	12.8	15.4
240	10.4	15.5	20.2	22.8	23.9	6.1	8.2	10.5	12.5	14.9
270	9.9	14.4	19.6	22.4	23.7	5.9	8.0	10.3	12.3	14.6
300	9.3	13.5	19.0	22.0	23.4	5.9	7.9	10.1	12.0	14.4
360	8.5	12.3	17.8	21.3	22.9	5.7	7.7	9.8	11.7	13.9
420	7.8	11.4	16.5	20.5	22.4	5.5	7.6	9.6	11.4	13.6
480	7.6	10.7	15.5	19.7	21.9	5.5	7.4	9.4	11.2	13.3
540	7.4	10.1	14.7	18.9	21.5	5.4	7.3	9.3	11.0	13.1
600	7.2	9.7	13.9	18.1	20.9	5.4	7.2	9.2	10.9	12.9
660	7.1	9.4	13.2	17.4	20.1	5.3	7.1	9.0	10.8	12.7
720	7.0	9.3	12.8	16.6	19.5	5.3	7.1	8.9	10.6	12.6
780	6.9	9.1	12.5	16.0	18.9	5.3	7.0	8.8	10.6	12.4
840	6.8	9.0	12.3	15.5	18.4	5.2	7.0	8.8	10.5	12.3
900	6.7	8.9	12.1	15.2	18.0	5.2	6.9	8.7	10.4	12.3
960				15.0	17.7					
1020				14.8	17.4					
1080					17.4					
1140					17.1					
1260					16.9					

6.5 Viscosity

Readings obtained with the Brookfield and Ferranti viscometers were multiplied by appropriate correction factors in order to produce the proper units of viscosity. It must be remembered that they are not comparable and so must be examined individually.

Table 9 gives the Brookfield scale readings using FAC and magnetite slurries respectively while Table 10 shows similar data from the Ferranti viscometer. Ambient temperatures during testing varied between 24°C and 25°C.

To convert to viscosity units the following factors were used:

Brookfield	6 rpm	scale x 1.0	=	mPa·S
	12	scale x 0.5		
	30	(scale - 0.1) x 0.2		
	60	(scale - 0.4) x 0.1		
Ferranti	1	scale x 0.02602		
	2	scale x 0.006074		
	3	scale x 0.002421		

The Ferranti data was then multiplied by 100 to give equivalent mPa·S numbers. Tables 11 and 12 present this information.

TABLE 9: Brookfield Gage Readings - FAC Media and Magnetite Media

	FAC				Magnetite			
	rpm				rpm			
S.G. of Media	6	12	30	60	6	12	30	60
1.3	1.5	2.5	5.5	10	0.5	2	6	11.5
1.4	3.5	10.5	15	66	1.5	2.5	5.5	12
1.5	10	12.5	27	44.5	2	3	7	20
1.6	23	26.5	35.9	56.5	3.5	14	26.5	37
1.7	66	78.5	98.5	100	100	100	100	100

TABLE 10: Ferranti Gage Readings - FAC Media and Magnetite Media

	FAC			Magnetite		
	Speed*			Speed*		
S.G. of Media	1	2	3	1	2	3
1.3	0.5	1.5	3.5	0.5	2.5	5
1.4	6.5	1.5	5	4	14	19
1.5	8	18.5	28	.5	11	17
1.6	15	20	32	7	11.5	22.5
1.7	37	46	68	15	24	36.6

*Speed 1 - 18 rpm, Speed 2 - 76.98 rpm, Speed 3 - 190.92 rpm

TABLE 11: Brookfield Viscosity mPa·S - FAC and Magnetite Media

	FAC				Magnetite			
	rpm				rpm			
S.G. of Media	6	12	30	60	6	12	30	60
1.3	1.5	1.25	1.08	0.96	0.5	1.00	1.18	1.11
1.4	3.5	5.25	2.98	6.56	1.5	1.25	1.08	1.16
1.5	10	6.25	5.38	4.41	2	1.5	1.38	1.96
1.6	23	13.25	7.16	5.61	3.5	7	5.28	3.66
1.7	66	39.25	19.68	9.96	100	50	19.98	9.96

TABLE 12: Ferranti Viscosity mPa·S - FAC Media and Magnetite Media

	FAC			Magnetite		
	Speed*			Speed*		
S.G. of Media	1	2	3	1	2	3
1.3	1.30	1.52	1.21	1.30	0.91	0.85
1.4	10.41	8.50	4.60	16.91	0.91	1.21
1.5	16.91	6.68	4.12	20.82	11.24	6.78
1.6	18.21	6.99	5.45	39.03	12.15	7.75
1.7	39.03	14.58	8.86	96.27	27.94	16.46

*Speed 1 - 18 rpm, Speed 2 - 76.98 rpm, Speed 3 - 190.92 rpm

6.6 Particle Abrasion

Table 13 gives the results of the 72 hour abrasion tests. As indicated previously there was a problem with the FAC data in that coupon weights often rose due to the accretion of material on their surfaces. To salvage some of this information the coupons were scraped and cleaned ultrasonically, the results of which are given in Table 14.

It can be seen that there was, in all cases, a loss in weight due to the abrasion of the heavy concentrate particles. However, with only two weights to examine it is not possible to determine the rate of abrasion which may or may not be constant over time. Another abrasion test was performed using a FAC S.G. 1.3 slurry and rigorous cleaning prior to each weighing. The results of this work are shown in Table 15 and Figure 6. It is evident that the weight loss due to abrasion is, within experimental error, a linear function over time after the first 24-36 hours.

TABLE 13: Abrasion Tests: Coupon Weights Over Time

S.G.	Coupon wt. (g) Initial	12h	24h	36h	48h	60h	72h
1.3 FAC	36.0349	36.0335	36.0322	36.0322	36.0311	36.0314	36.0294
Mag	36.3155	36.3113	36.3087	36.3062	36.3045	36.3014	36.2988
1.5 FAC	36.5017	36.5030	36.5006	36.4997	36.5002	36.4990	36.4979
Mag	36.5182	36.5156	36.5117	36.5288	36.5420	36.5419	36.4997
1.7 FAC	36.4477	36.4473	36.4490	36.4526	36.4596	36.4667	36.4808
Mag	37.5554	37.5525	37.5509	37.5499	37.5486	37.5420	37.5331

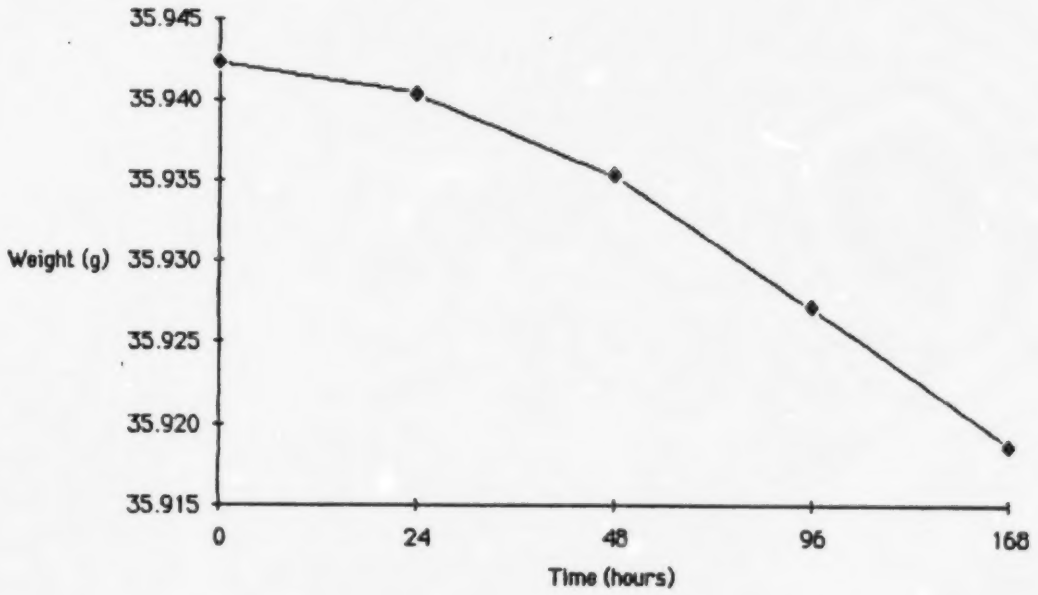
TABLE 14: Coupon Weights After Cleaning

Test Coupon	Initial wt (g)	Wt. After Cleaning (g)	Wt. Loss (g)
#1 - FAC S.G. 1.3	36.0349	36.0238	0.0111
#2 - FAC S.G. 1.5	36.5017	36.4898	0.0119
#3 - FAC S.G. 1.7	36.4477	36.4347	0.0130
#4 - Magnetite S.G. 1.3	36.3155	36.2948	0.0207
#5 - Magnetite S.G. 1.5	36.5182	36.4970	0.0212
#6 - Magnetite S.G. 1.7	37.5554	37.5301	0.0253

TABLE 15: Abrasion Test FAC S.G. 1.3 Weight Over Time

Time	0 hours	24	48	96	168
wt.	35.9423g	35.9404	35.9354	35.9272	35.9186

FIGURE 6: Abrasion Test FAC S.6. 1.3



6.7 Particle Attrition

There was no evidence of particle attrition in any of the four abrasion tests regardless of media type or specific gravity. Table 16 presents a summary of the results obtained from Automated Image Analysis of the six samples in question as well as previously presented data for the raw FAC and magnetite samples (prior to abrasion testing). Plates 4 and 5 are of magnetite before and after the abrasion tests. There is no apparent difference between the two materials. Figures 7-12 show AIA histograms of particle size distribution for FAC and Magnetite from abrasion tests using media of S.G. 1.3, 1.5 and 1.7. Tables 17-22 give the corresponding information in tabular form.

TABLE 16: Comparison of Particle Size Distribution Before and After Abrasion Testing

	Particle Size (microns)			
	Minimum	Maximum	Mean	Standard Deviation
Raw FAC	0.8	30.0	4.2	1.8
FAC From S.G. 1.3 Test	0.6	108.7	2.4	2.1
1.5	1.2	26.5	4.7	1.8
1.7	0.6	34.2	2.8	2.2
Raw Magnetite	0.5	29.6	2.0	2.1
Magnetite From S.G. 1.3 Test	0.6	55.3	2.7	2.0
1.5	0.5	35.2	1.7	2.1
1.7	0.6	108.7	1.9	2.0

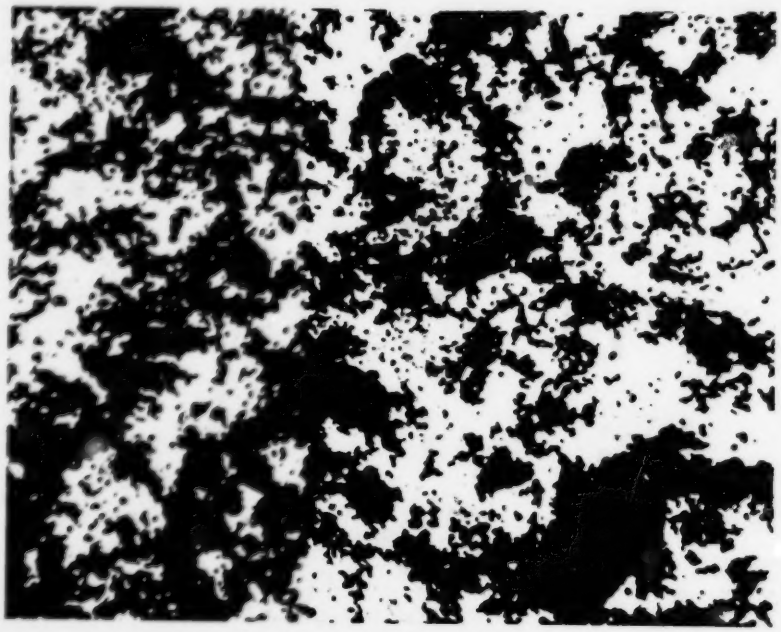


Plate 4 Magnetite Before Abraison Test

Scale 1 cm = 44 microns

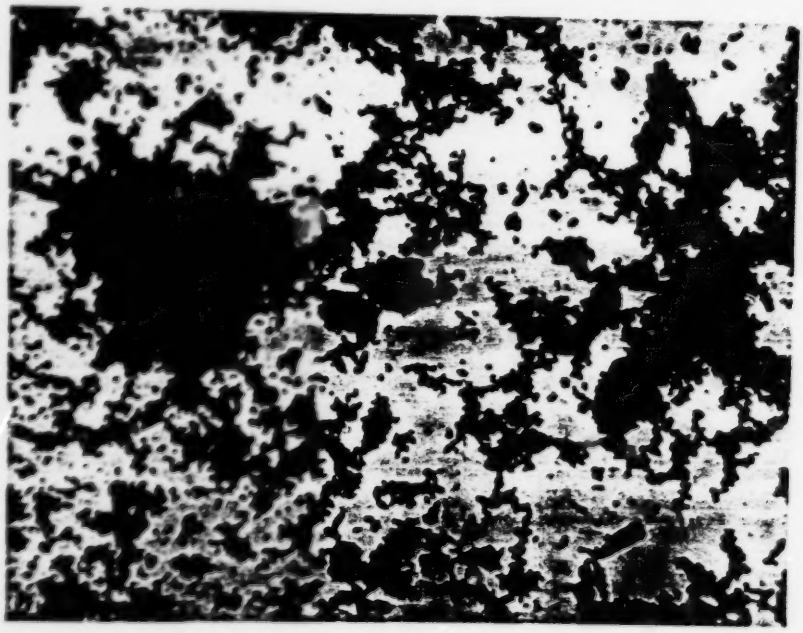


Plate 5 Magnetite After Abraison Test

Scale 1 cm = 44 microns

Figure 7. Histograms of FAC Particle Size Distribution After S.G. 1.3 Abrasion Test

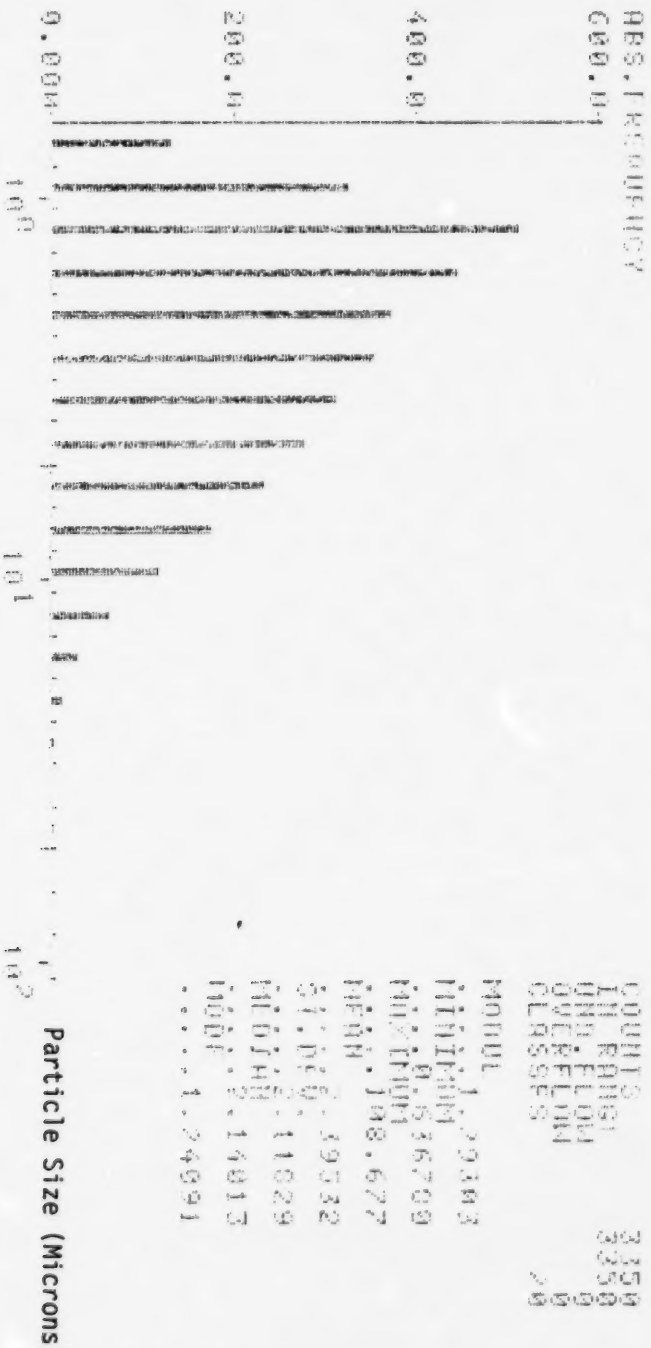


TABLE 17

Size Class List of FAC Particle Size Distribution After S.G. 1.3 Abrasion Test

Class	From	To	Frequencies			
			ABS	REL	CUM. ABS	CUM. REL
1	.63678	.82337	130.	3.88 %	130.	3.88 %
2	.82337	1.0646	323.	9.64 %	453.	13.52 %
3	1.0646	1.3766	510.	15.22 %	963.	28.75 %
4	1.3766	1.7800	446.	13.31 %	1409.	42.06 %
5	1.7800	2.3016	371.	11.07 %	1780.	53.13 %
6	2.3016	2.9760	351.	10.48 %	2131.	63.61 %
7	2.9760	3.8481	311.	9.28 %	2442.	72.90 %
8	3.8481	4.9756	277.	8.27 %	2719.	81.16 %
9	4.9756	6.4336	233.	6.96 %	2952.	88.12 %
10	6.4336	8.3188	174.	5.19 %	3126.	93.31 %
11	8.3188	10.756	116.	3.46 %	3242.	96.78 %
12	10.756	13.908	62.	1.85 %	3304.	98.63 %
13	13.908	17.984	27.	.81 %	3331.	99.43 %
14	17.984	23.254	13.	.39 %	3344.	99.82 %
15	23.254	30.068	3.	.09 %	3347.	99.91 %
16	30.068	38.878	0.	0.00 %	3347.	99.91 %
17	38.878	50.271	2.	.06 %	3349.	99.97 %
18	50.271	65.001	0.	0.00 %	3349.	99.97 %
19	65.001	84.048	0.	0.00 %	3349.	99.97 %
20	84.048	108.68	1.	.03 %	3350.	100.00 %

Figure 8. Histogram of FAC Particle Size Distribution After S.G. 1.5 Abrasion Test.

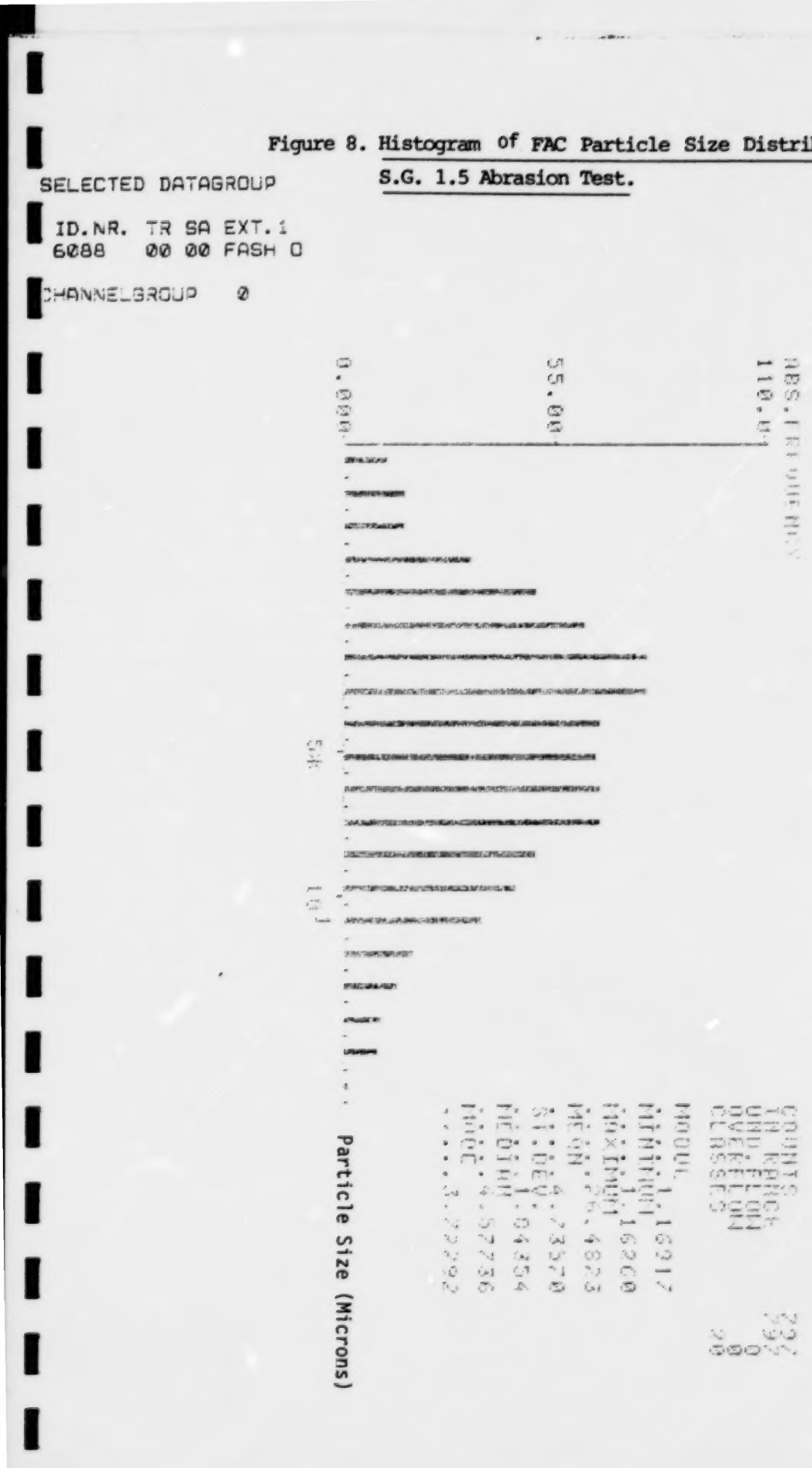


TABLE 18

Size Class List of FAC Particle Size Distribution After S.G. 1.5 Abrasion Test

Class	From	To	Frequencies			
			ABS	REL	CUM. ABS	CUM. REL
1	1.1626	1.3593	11.	1.38 %	11.	1.38 %
2	1.3593	1.5892	16.	2.01 %	27.	3.39 %
3	1.5892	1.8581	16.	2.01 %	43.	5.40 %
4	1.8581	2.1724	33.	4.14 %	76.	9.54 %
5	2.1724	2.5399	50.	6.27 %	126.	15.81 %
6	2.5399	2.9695	63.	7.90 %	189.	23.71 %
7	2.9695	3.4719	79.	9.91 %	268.	33.63 %
8	3.4719	4.0592	79.	9.91 %	347.	43.54 %
9	4.0592	4.7459	67.	8.41 %	414.	51.94 %
10	4.7459	5.5487	66.	8.28 %	480.	60.23 %
11	5.5487	6.4874	67.	8.41 %	547.	68.63 %
12	6.4874	7.5848	67.	8.41 %	614.	77.04 %
13	7.5848	8.8679	50.	6.27 %	664.	83.31 %
14	8.8679	10.368	45.	5.65 %	709.	88.96 %
15	10.368	12.122	36.	4.52 %	745.	93.48 %
16	12.122	24.173	18.	1.16 %	763.	95.73 %
17	14.173	16.570	14.	1.76 %	777.	97.49 %
18	16.570	19.373	10.	1.25 %	787.	98.75 %
19	19.373	22.651	9.	1.13 %	796.	99.87 %
20	22.651	26.482	1.	.13 %	797.	100.00 %

Figure 9. Histogram of FAC Particle Size Distribution After S.G. 1.7 Abrasion Test.

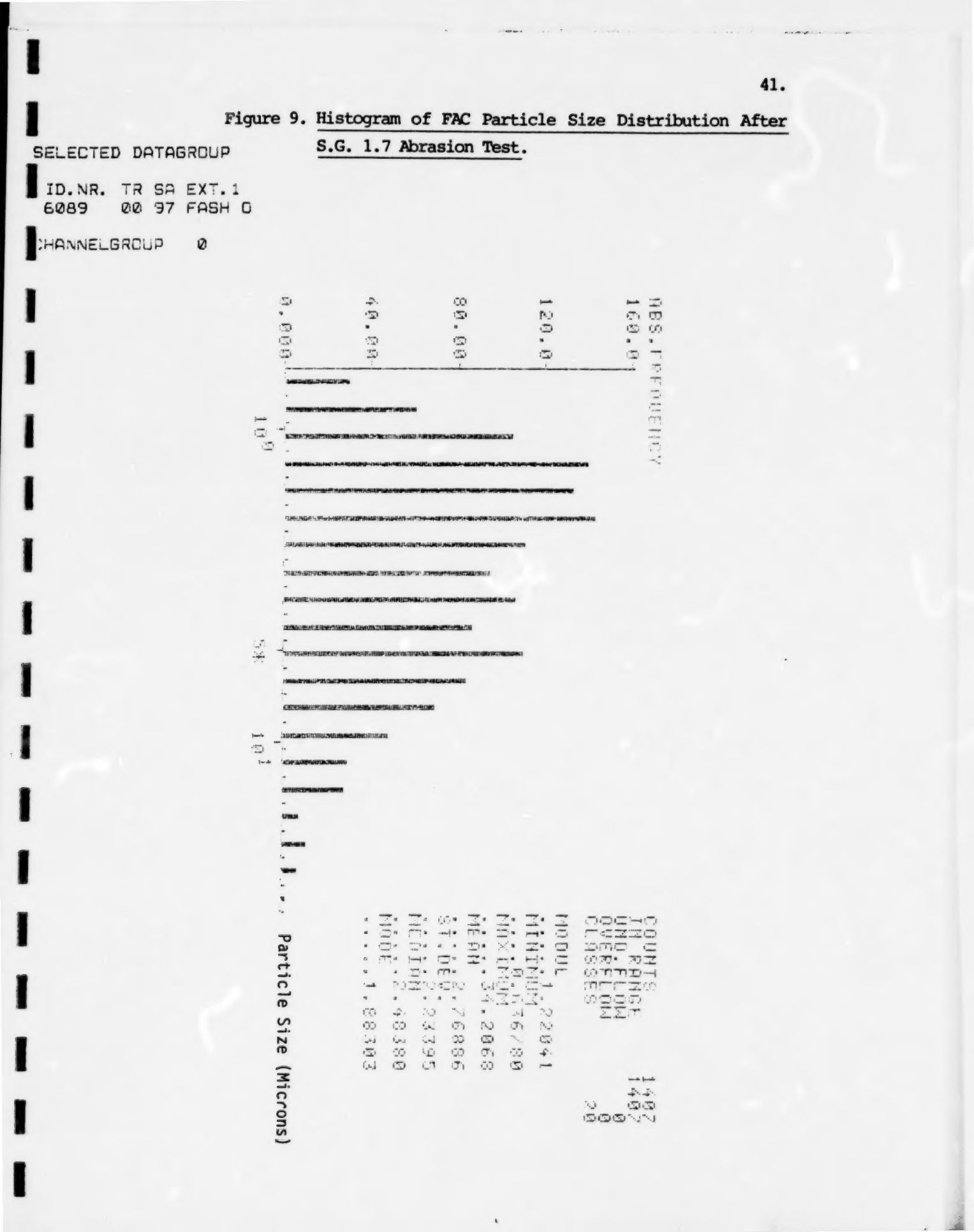


TABLE 19

Size Class List of FAC Particle Size Distribution After S.G. 1.7 Abrasion Test

Class	From	To	Frequencies			
			ABS	REL	CUM. ABS	CUM. REL
1	.63678	.77713	30.	2.13 %	30.	2.13 %
2	.77713	.94842	60.	4.26 %	90.	6.40 %
3	.94842	1.1575	105.	7.46 %	195.	13.86 %
4	1.1575	1.4126	140.	9.95 %	335.	23.81 %
5	1.4126	1.7239	133.	9.45 %	468.	33.26 %
6	1.7239	2.1039	143.	10.16 %	611.	43.43 %
7	2.1039	2.5676	111.	7.89 %	722.	51.31 %
8	2.5676	3.1336	95.	6.75 %	817.	58.07 %
9	3.1336	3.8242	107.	7.60 %	924.	65.67 %
10	3.8242	4.6671	86.	6.11 %	1010.	71.78 %
11	4.6671	5.6958	110.	7.82 %	1120.	79.60 %
12	5.6958	6.9513	84.	5.97 %	1204.	85.57 %
13	6.9513	8.4834	69.	4.90 %	1273.	90.48 %
14	8.4834	10.353	48.	3.41 %	1321.	93.89 %
15	10.353	12.635	30.	2.13 %	1351.	96.02 %
16	12.635	15.420	28.	1.99 %	1379.	98.01 %
17	15.420	18.819	8.	.57 %	1387.	98.58 %
18	18.819	22.967	11.	.78 %	1398.	99.36 %
19	22.967	28.029	7.	.50 %	1405.	99.86 %
20	28.029	34.207	2.	.14 %	1407.	100.00 %

Figure 10. Histogram of Magnetite Particle Size Distribution After S.G. 1.3 Abrasion Test.

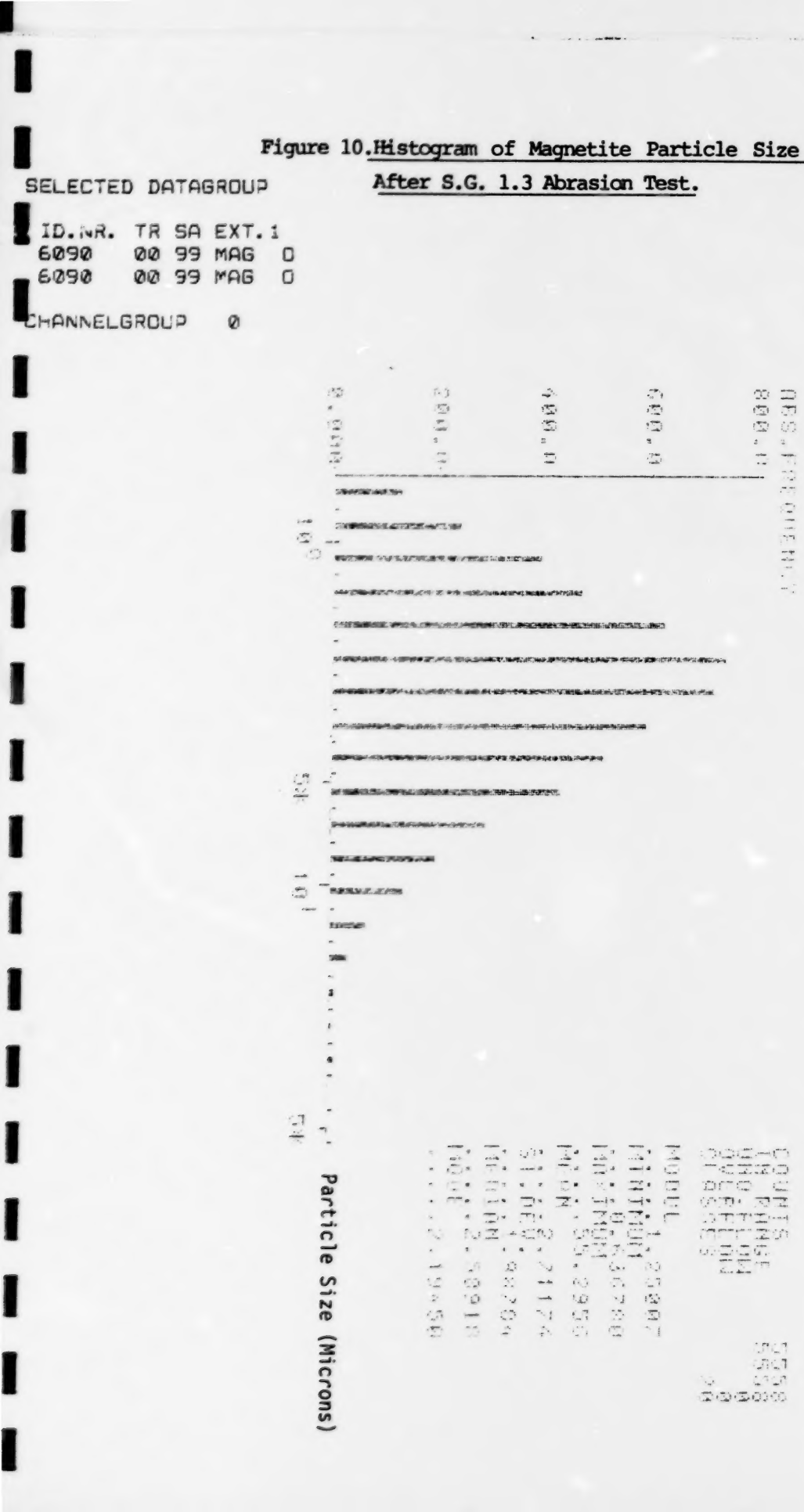


TABLE 20

Size Class List of Magnetite Size Distribution After S.G. 1.3 Abrasion Test

Class	From	To	Frequencies			
			ABS	REL	CUM. ABS	CUM. REL
1	.63678	.79602	126.	2.27 %	126.	2.27 %
2	.79602	.99508	236.	4.25 %	362.	6.51 %
3	.99508	1.2439	388.	6.98 %	750.	13.49 %
4	1.2439	1.5550	464.	8.35 %	1214.	21.84 %
5	1.5550	2.9439	624.	11.23 %	1838.	33.07 %
6	1.9439	2.4300	738.	13.28 %	2576.	46.35 %
7	2.4300	3.0376	714.	12.85 %	3290.	59.19 %
8	3.0376	3.7973	588.	10.58 %	3878.	69.77 %
9	3.7973	4.7468	508.	9.14 %	4386.	78.91 %
10	4.7468	5.9339	428.	7.70 %	4814.	86.61 %
11	5.9339	7.4178	286.	5.15 %	5100.	91.76 %
12	7.4178	9.2728	196.	3.53 %	5296.	95.29 %
13	9.2728	11.592	134.	2.41 %	5430.	97.70 %
14	11.592	14.490	68.	1.22 %	5498.	98.92 %
15	14.490	18.114	34.	.61 %	5532.	99.53 %
16	18.114	22.644	8.	.14 %	5540.	99.68 %
17	22.644	28.307	6.	.11 %	5546.	99.78 %
18	28.307	35.385	8.	.14 %	5554.	99.93 %
19	35.385	44.234	2.	.04 %	5556.	99.96 %
20	44.234	55.296	2.	.04 %	5558.	100.00 %

Figure 11. Histogram of Magnetite Particle Size Distribution After S.G. 1.5 Abrasion Test.

SELECTED DATAGROUP

ID.NR. TR SA EXT.1
6091 00 99 MAG 0

CHANNELGROUP 0

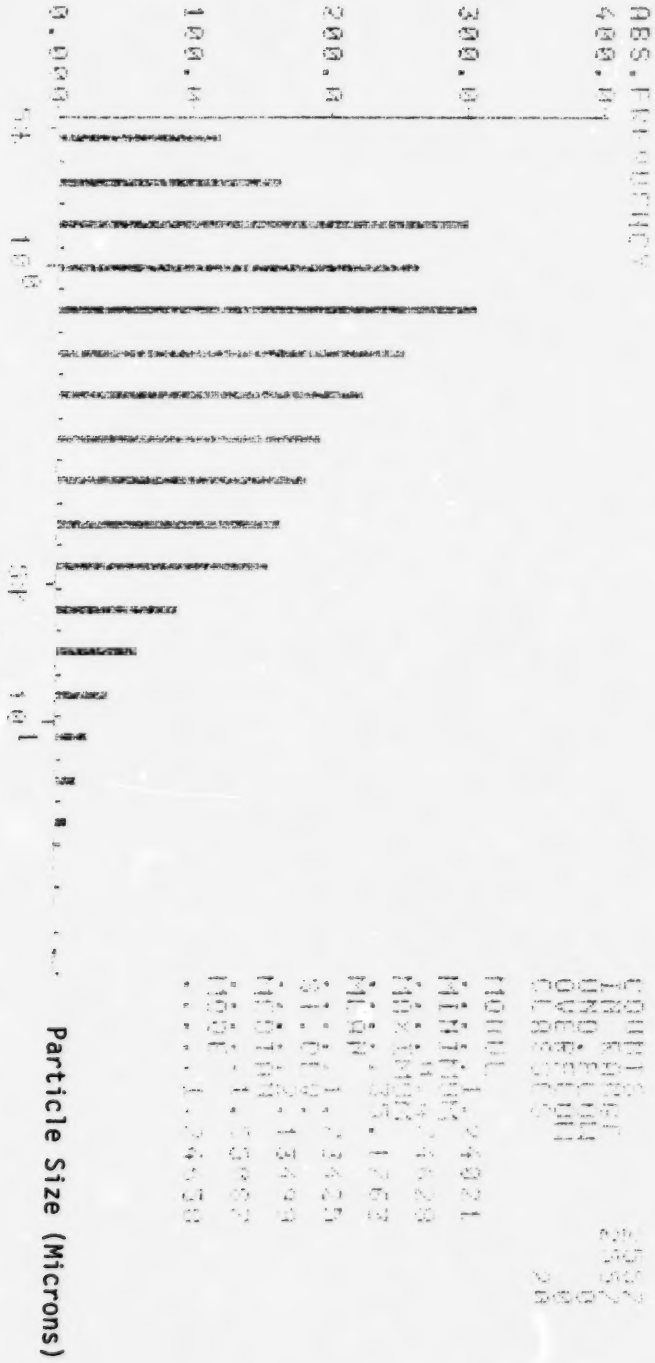


TABLE 21

Size Class List of Magnetite Size Distribution After S.G. 1.5 Abrasion Test

Class	From	To	Frequencies			
			ABS	REL	CUM. ABS	CUM. REL
1	.47463	.58864	118.	4.61 %	118.	4.61 %
2	.58864	.73003	163.	6.37 %	281.	10.99 %
3	.73003	.90539	300.	11.73 %	581.	22.72 %
4	.90539	1.1229	265.	10.36 %	846.	33.09 %
5	1.1229	1.3926	306.	11.97 %	1152.	45.05 %
6	1.3926	1.7271	253.	9.89 %	1405.	54.95 %
7	1.7271	2.1420	224.	8.76 %	1629.	63.71 %
8	2.1420	2.6565	192.	7.51 %	1821.	71.22 %
9	2.6565	3.2946	181.	7.08 %	2002.	78.29 %
10	3.2946	4.0860	164.	6.41 %	2166.	84.71 %
11	4.0860	5.0675	155.	6.06 %	2321.	90.77 %
12	5.0675	6.2848	89.	3.48 %	2410.	94.25 %
13	6.2848	7.7945	59.	2.31 %	2469.	96.56 %
14	7.7945	9.6668	38.	1.49 %	2507.	98.04 %
15	9.6668	11.989	24.	.94 %	2531.	98.98 %
16	11.989	14.869	14.	.55 %	2545.	99.53 %
17	14.869	18.440	8.	.31 %	2553.	99.84 %
18	18.440	22.870	1.	.04 %	2554.	99.88 %
19	22.870	28.363	1.	.04 %	2555.	99.92 %
20	28.363	35.176	2.	.08 %	2557.	100.00 %

Figure 12. Histogram of Magnetite Particle Size Distribution After S.G. 1.7 Abrasion Test.

SELECTED DATAGROUP

ID.NR.	TR	SA	EXT.	1
6092	00	00	MAG	0
6092	00	00	MAG	0

CHANNELGROUP 0

TABLE 22

Size Class List of Magnetite Size Distribution After S.G. 1.7 Abrasion Test

Class	From	To	Frequencies			
			ABS	REL	CUM. ABS	CUM. REL
1	.82337	.63678	536.	4.71 %	536.	4.71 %
2	1.0646	.82337	1160.	10.20 %	1696.	14.91 %
3	1.3766	1.0646	1428.	12.55 %	3124.	27.46 %
4	1.7800	1.3766	1690.	14.86 %	4814.	42.32 %
5	2.3016	1.7800	1622.	14.26 %	6436.	56.58 %
6	2.9760	2.3016	1496.	13.15 %	7932.	69.73 %
7	3.8481	2.9760	1226.	10.78 %	9158.	80.50 %
8	4.9756	3.8481	900.	7.91 %	10058.	88.41 %
9	6.4336	4.9756	590.	5.19 %	10648.	93.60 %
10	8.3188	6.4336	400.	3.52 %	11048.	97.12 %
11	10.756	8.3188	178.	1.56 %	11226.	98.68 %
12	13.908	10.756	90.	.79 %	11316.	99.47 %
13	17.984	13.908	34.	.30 %	11350.	99.77 %
14	23.254	17.984	12.	.11 %	11362.	99.88 %
15	30.068	23.254	6.	.05 %	11368.	99.93 %
16	38.878	30.068	2.	.02 %	11370.	99.95 %
17	50.271	38.878	2.	.02 %	11372.	99.96 %
18	65.001	50.271	2.	.02 %	11374.	99.98 %
19	84.048	65.001	0.	0.00 %	11374.	99.98 %
20	108.68	84.048	2.	.02 %	11376.	100.00 %

6.8 Corrosion

Slurry pH's measured during abrasion testing are given in Table 23. In all cases the media pH's were mildly basic and decreased slightly as time went by.

6.9 Retention of Magnetic Properties

Processing of the FAC and magnetite prior to abrasion testing and then again with the solids from the S.G. 1.5 media after testing produced the following comparative results (Table 24). Numbers are the average of 2 runs in each case.

TABLE 23: Heavy Media pH

Slurry	pH										
	0 hrs	12	24	36	48	60	72	96	120	144	168
FAC S.G. 1.3	8.2	8.2	8.2	8.2	8.1	7.9	7.9				
FAC S.G. 1.5	8.2	8.1	8.1	8.1	8.1	7.7	7.7				
FAC S.G. 1.7	7.4	7.8	7.8	7.8	7.7	7.6	7.5				
Mag S.G. 1.3	7.2	7.7	7.7	7.6	7.6	7.6	7.3				
Mag S.G. 1.5	7.8	7.8	7.8	7.7	7.5	7.5	7.6				
Mag S.G. 1.7	8.0	8.0	8.1	7.9	7.6	7.6	7.3				
Repeat FAC SG 1.3	8.1	--	8.4	--	8.0	--	--	7.9	--	--	7.8

TABLE 24

Percentage Magnetics Before and After Abrasion Testing

	Before Testing	After Testing - Solids from S.G. 1.5 Media
FAC	94.0	94.9
Magnetite	90.8	92.8

7.0 ASSESSMENT

7.1 Size and Density

As the density of magnetite is substantially greater than that of the fly ash, smaller amounts of magnetite are needed to produce media of a particular S.G. and there will be corresponding differences in the rheological properties.

It appears that the differing results obtained from the sieve and AIA analyses are due to the tendency on the part of the magnetite to form aggregates because of its highly magnetic nature. The AIA showed virtually no difference in size. It will be recalled that both FAC and magnetite samples were demagnetized prior to processing by AIA and so these results are consistent with visual observation. Plates 6 and 7 are photomicrographs of a magnetite sample before and after demagnetization. The large aggregates are clearly visible in the former while in the latter they are reduced in size. It is this tendency of the magnetite to agglomerate that leads it to act as though it were composed of larger particles than is actually the case. This is evident in both settling and viscosity tests.

7.2 Media Stability

It is apparent that the greater density of the magnetite particles, coupled with their tendency to aggregate is the primary cause of it settling faster from slurry than the FAC. At a media S.G. of 1.3 the difference in the settling rates is 3.3 times, increasing with increasing S.G. to roughly 8 times at S.G. 1.7.

Figure 5 indicates the fact that the rate of sedimentation decreases with increasing specific gravity of the slurry. This is true in the cases of both FAC and magnetite.

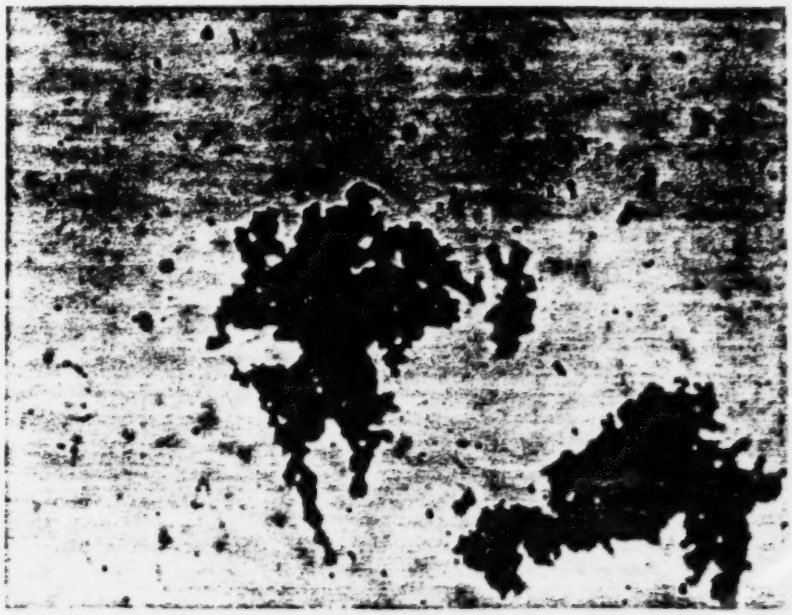


Plate 6 Magnetite Before Demagnetization

1 cm = 44 microns

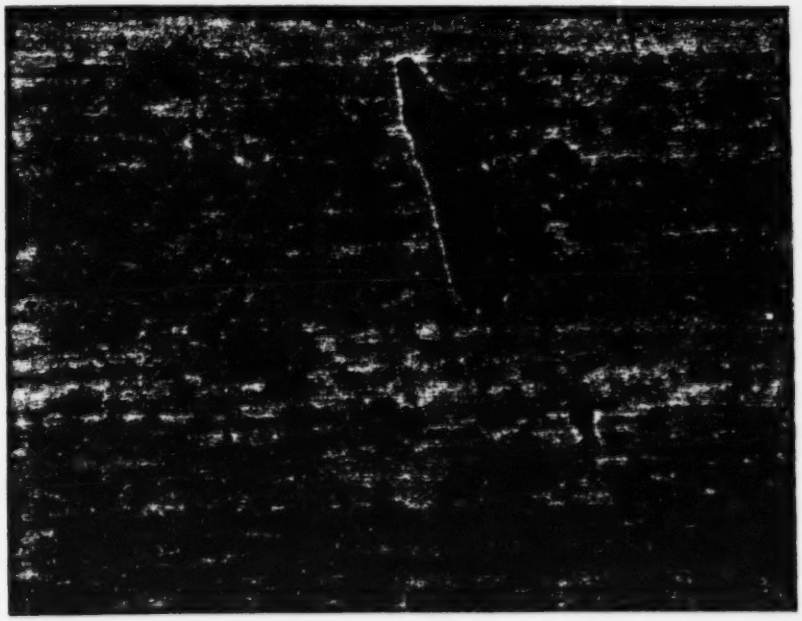


Plate 7 Magnetite After Demagnetization

1 cm = 44 microns

Although the FAC particles are less irregular in shape than those of the magnetite this does not seem to affect the settling rate noticeably. The round nature of the grains should lead to somewhat increased settling rates but apparently the large particle size difference overshadows this effect.

7.3 Viscosity

Regardless of the type of viscometer used both the FAC and magnetite exhibited increasing viscosity with increasing media specific gravity. Similarly, as the speed at which the measurements were made was increased a corresponding decrease in viscosity was noted.

From previous work done by others it has been shown that the finer the particles in a given media the greater the viscosity will be at a given solids concentration. The results obtained and recorded in Tables 11 and 12 bear this out. The figures from both the Brookfield and Ferranti viscometers indicate this fact although there is reversal of this at Media S.G. 1.7 and 6 and 12 rpm using the former unit. This is probably due to experimental error. Further, it is known that round particles in slurry yield lower viscosities than angular particle media of the same concentration. This combined with the relatively smaller FAC particle size, produced media of a more viscous nature under all conditions of slurry S.G. and viscometer speed.

7.4 Particle Abrasion

From the 72 hour abrasion tests it can be seen that a loss in weight did occur with time. It may also be noted that increased media S.G. leads to increased weight loss. Further, it is evident that the magnetite produced a greater weight loss at any given media S.G. (almost twice as much in each case) than did the FAC. This latter point is to be expected and is due to the denser, more irregular make-up of the magnetite grains.

The 168 hour FAC S.G. 1.3 test reveals two points of interest:

1) The total weight loss over the 7 day period was 0.0237 grams. Assuming linearity of the process this yields a 72 hour loss of 0.0102 g which compares favourably with the equivalent figure of 0.0111 g found in the last column of Table 14.

2) A plot of weight vs time (Figure 6) shows that the abrasion process is approximately linear (after the first 24 hours) and so the above assumption (1) can be safely made.

7.5 Particle Attrition

Although no particle attrition was in evidence in any of the tests it is possible that the test period, being only 72 hours in length, was too short to make an accurate determination. It is felt that several weeks of non-stop agitation would be necessary to gain a true understanding of the situation.

7.6 Corrosion

It would appear that corrosion played a very small part in the loss of weight experienced by the aluminum test coupons during testing. The highest pH recorded at any time was 8.2 at the beginning of a run while the lowest at the end of any test was 7.3. pH almost always dropped as time went by, although by only 9% maximum and usually by only 2-3%. At such nearly neutral pH's it is not likely that there would be excessive corrosion problems encountered with any of the construction materials commonly used in coal beneficiation plants.

7.7 Retention of Magnetic Properties

Although the figures given in Table 24 show small changes in the magnetics contents of the two materials, they are not

particularly significant. Given the rather crude nature of the method used to determine these figures it is reasonable to assume that changes of ±5% would be common. In light of this, it can probably be said that little actual change takes place.

8.0 COMPARISON WITH ISO SPECIFICATION

ISO Draft Proposal DP8833, The Testing of Magnetite For Use in Coal Preparation, specifies the testing of the following properties which it is felt define the suitability of a magnetite for use in the processing of coal:

a) Moisture content
b) Particle size distribution
c) Magnetic content
d) Fundamental magnetic properties
e) Relative density
f) Total iron content
g) Ferrous iron content

Comments on each of these areas of investigation are made relative to the work actually carried out during this contract.

8.1 Moisture Content

The as-received magnetite used in this work arrived in slurried form and so the first step was to decant the water and dry the solids.

The Fly Ash Concentrate was prepared using wet magnetic separation techniques and again was dried prior to any subsequent use.

In light of this, the determination of moisture content had no bearing on the work undertaken. In fact, ISO specification is concerned mainly with the cost and safety of shipment which would obviously be influenced by the amount of water contained in the sample.

8.2 Particle Size Distribution

ISO suggests the use of test sieves and a sub-sieve classifier with sub-sieve being taken to mean less than 38 microns. Automated Image Analysis, as described in Section 5.2, was used in the RPC work. It is generally accepted that such a technique is highly accurate and a good substitute for the former method.

8.3 Magnetic Content

The ISO Specification, Section 9.2 states the following: "The preferred test method is specified in detail, alternatively the commercially available Davis tube tester or any other such similar apparatus may be used provided a multiple pass procedure is adopted in order to ensure total recovery of magnetic material." According to the literature all such methods are somewhat approximate and so, this being the case, it was decided to use the Carpco wet magnetic separator to make this determination. The reject material was collected and passed through the device several times to ensure that all the magnetics had been separated. Results compare favourably with those indicated by Mitas (Reference 2) in Table 25 below.

Table 25 : % Magnetics Comparison

	Mitas*	RPC**
FAC	96.1	94.5
Magnetite	93.9	91.8

*Average of 3 FAC and 3 magnetite samples.

**Average of 2 FAC and 2 magnetite determinations (1 sample of each).

8.4 Fundamental Magnetic Properties

The following is taken from Section 10 of ISO Standard DP8833.

"The determination of suitable parameters requires very specialized apparatus and techniques and is probably best undertaken by a University or Research Institute used to such measurement.

NOTE - There is a lack of concensus as to which magnetic parameters are relevant in the context of this standard therefore it is left open for the interested parties to decide which property to measure. However, there is some evidence to suggest that the coercivity is a guide to the ease of recovery of a magnetite and that the saturation magnetic moment is a measure of the purity of the actual magnetite grains."

As there is still some discussion as to whether the measurement of the fundamental properties of magnetite is a worthwhile exercise and as said measurement is somewhat difficult they were not undertaken. Further, there is good evidence to suggest that particle size is a reasonable indicator of the ease of recovery of the product.

8.5 Relative Density

Section 11.1: "The relative density shall be determined using the relative density bottle method in which the volume of liquid displaced by a known mass of sample is measured." The technique used during this work was similar.

8.6 Iron Content

The iron content measurements indicated as pertinent by ISO were adequately covered in this work by determining Fe_2O_3 (FAC), Fe_3O_4 (Magnetite) plus trace Fe in each case.

8.7 Other

In addition to the areas of interest specified by ISO, it is felt that the determination of such quantities as media stability, viscosity and particle attrition/abrasion/corrosion should also be examined in order to fully assess a material's worth in the beneficiation of coal.

9.0 CONCLUSIONS/RECOMMENDATIONS

From the preceeding work a number of overall conclusions can be reached. These are given below in point form.

-The FAC and magnetite particle distributions found in the samples used were similar. The density of the magnetite particles is greater than that of the FAC particles and so the solids loading is greater in the latter case. However, these levels are not high enough to be of concern for use in coal cleaning circuits.

-The FAC is more stable in slurry than the commercial magnetite tested. This is true of all media S.G. examined (see Figure 5, Page 26).

-The FAC media are more stable than -325 mesh Pennsylvania FAM media and equally stable when compared with Reiss-Viking 965 Magnetite media.

-FAC media are somewhat more viscous than their magnetite counterparts but not enough it is felt to present any major problems for use in coal beneficiation.

-FAC particles, because of their lower density and rounder shape, are not as abrasive as magnetite particles.

-No particle attrition was observed at any media S.G. using FAC or magnetite.

-FAC media pH's are similar to those of magnetite media and so should present no greater corrosion problems.

-FAC particles retain their magnetic properties as well as magnetite.

From the above summary it is quite clear that FAC media perform at least equally well to commercial magnetite media and in some cases in a superior fashion. This would indicate the potential that such media have for use as coal beneficiation agents and it is recommended that such trials be carried out to determine whether or not the results are as promising as this work would suggest.

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1. Abbott, D., 1983; Preparation of a high specific gravity concentrate from the iron-rich fly ash of the Minto Coal, New Brunswick, RPC Report AS/84/21.

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4. Graham, C.C. and Lamb, R., 1982; Coal Preparation - Dense Media Rheology and Review of Measurement and Control, Australian Coal Industry Research Laboratories Ltd., P.R. 82-3.

5. Birlingmair, D.; Murtha, M. and Killmeyer, R.; Characterization and Performance Evaluation of Fly Ash Derived Heavy-Medium Material.

AUTHORIZATION

DEPARTMENT: APPLIED SCIENCE

PROJECT TITLE: COMPARATIVE EXAMINATION OF FLY ASH AND MAGNETITE HEAVY MEDIA FOR COAL BENEFICIATION

PROJECT NUMBER: 05000223 PROPOSAL NUMBER

REPORT AS/87/14

Prepared By: K.T. Fraser

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Date: 26 August 1986

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APPENDICES

A Statement of Work

B Comparative Examination of Fly Ash and Magnetite Heavy Media for Coal Beneficiation. RPC Report AS/87/1

APPENDIX A

APPENDIX "A"

STATEMENT OF WORK

1. Preparation of high density magnetite fraction from Fly Ash

The objective is recovering the highest relative density fraction from fly ash at reasonable yield (about 100kg) for heavy media tests. Tests will be carried (out) to optimize the recovery of high density magnetic fraction. Chemical and physical properties of the fly ash will be determined before and after concentration to characterize the different starting minerals and products.

2. Comparative testing of Fly Ash and Magnetite Heavy Media

a) Acquire a magnetite sample from commercial material used at an operating heavy media plant.

b) Evaluate the rheology of a fly ash heavy media against one prepared from magnetite.

Aspects to be investigated will include:

- media stability
- size distribution and relative density
- viscosity
- solid loading (% solid by volume) and specific gravity
- particle attrition/abrasion/corrosion
- intensity and retention of magnetic properties

Standard tests will be used to evaluate each property and comments are required in comparison with ISO specification.

3. Reporting

The final report in fifteen (15) copies is to be submitted at the conclusion of the work and this report must describe the work undertaken and give results on the properties and use of the high density magnetic fractions. The results should be adequate to make a laboratory comparison between the properties and use of media prepared from fly ash concentrate and from magnetite in coal cleaning by heavy media separation. Conclusions will be reached on the production of a concentrate from the Minto fly ash. Monthly progress reports should be submitted with invoices to the Scientific Authority.

APPENDIX B

COMPARATIVE EXAMINATION OF FLY ASH AND MAGNETITE HEAVY MEDIA FOR COAL BENEFICIATION

Progress Report No. 1

Scientific Authority
J. Szmanski
CANMET Coal Research Laboratories
555 Booth Street
Ottawa, K1A 0G1

Job No.: 50223
Report No.: AS/87/1
April 2, 1986

D. Abbott, Manager
Energy Projects

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INTRODUCTION

The contract, received in mid February, was arranged so that the first part dealing with the preparation of a high density magnetic fraction from the Minto fly ash would be completed by March 31, 1986. Immediately on receipt of the contract a request was made to the New Brunswick Electric Power Commission for a supply of fly ash from their pulverized coal burner at the Grand Lake generating station. This was delivered in early March after which work could commence. This progress report describes the efforts to prepare a magnetic concentrate of high specific gravity and the start of the preparation of an adequate quantity of fly ash magnetic concentrate for the test program.

NATURE OF FLY ASH

The fly ash used in this project is 77 % minus 325 mesh (-44 microns) when wet sieved.

The fly ash is iron-rich as is shown in Table 1 which gives the chemical composition of the ash. Note that the ash contains about 10 per cent unburnt carbon. Other RPC work has shown that the ash contains about 2 per cent cenospheres. The other material in the ash is in the form of spherules of an opaque glass with magnetic iron oxide inclusions. Most of the ash is magnetic because more than 90 per cent is lifted by a hand magnet. Work in this project was directed at separating out the highly magnetic material from the less magnetic or non-magnetic ash.

PREPARATION OF HIGH SPECIFIC GRAVITY FRACTION

Screening

Dry sieving of the bulk fly ash and specific gravity (SG) determination of the different fraction gave the following results:

Sample	wt %	SG
bulk fly ash	-	2.97
+ 100	2	1.75
100-270	52	2.58
270-325	33	3.28
-325	13	3.37

The progessive increase in SG with decrease in grain size meant that only -325 mesh ash was used in the preparation of a concentrate. Note that when wet sieved all but 20 to 25 per cent of the ash passes through the 325 mesh sieve.

Magnetic Concentration

A Carpco wet magnetic concentrator was used. Mineral separation took place in a box of 3" x 3" cross section between the poles of an electromagnet. The box was filled with $\frac{1}{2}$ inch iron balls to provide an adhering surface for the magnetic particles. The magnet was adjusted to a particular strength and a portion of slurried fly ash poured in and washed. During these tests settings of 2, 4 and 6 on the high intensity scale were used. After washing the magnet was turned off and the retained magnetics washed out and collected as the concentrate.

Specific gravity of fractions were determined by ASTM C188-72 using a Le Chatelier flask and, when only smaller quantities of sample were available, with a 50 ml measuring flask.

Trial tests to optimize the fly ash production of a magnetic concentrate were conducted on the as-received bulk fly ash, 270-0 mesh, 270-325 mesh and 325-0 mesh ash. The results are given in Table 2. These tests confirmed that it was possible to obtain a magnetic concentrate of SG 3.9 or higher. The yields of 60 per cent seem a bit high. It was expected to drop when large scale production was commenced.

Because the finer material is of highest SG and because magnetite for heavy media separation is -325 mesh in size it was decided to concentrate on that fraction for the preparation of quantities of concentrate. The bulk fly ash was milled for various periods to reduce it to -325 mesh and a magnetic concentrate prepared. (Table 3)

These tests showed that rough concentration gave a magnetic concentrate of SG 3.7 at about 45 per cent yield. Rewashing with the magnetic separator set at a lower intensity gave a concentrate of SG 3.9 but yeild was reduced to about 20 per cent.

Production of concentrate is taking place now so that there will be adequate material for the characterization tests.

CHEMICAL COMPOSITION

Various fractions were analysed for iron in order to show the relationship of iron content to SG. This information is given in Table 4.

AUTHORIZATION

DEPARTMENT: APPLIED SCIENCES

PROJECT TITLE: COMPARATIVE EXAMINATION OF FLY ASH AND MAGNETITE HEAVY MEDIA FOR COAL BENEFICIATION

PROJECT NUMBER: 50223 PROPOSAL NUMBER

REPORT AS/87/1

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TABLE 1

ANALYSIS OF BULK ASH

Element	Wt per cent Average	Range
Silicon	33.6	13.5 - 49.3
Aluminum	18.2	7.7 - 26.0
Iron	38.1	14.1 - 71.6
Titanium	0.6	0.1 - 0.9
Phosphorus	1.7	0.5 - 3.4
Calcium	3.2	0.9 - 5.7
Magnesium	1.0	5.6
Sulphur	2.6	5.6
Sodium	0.4	1.1
Potassium	1.3	0.3 - 0.4
Maganese	0.2	0.1 - 0.3

Average of 250 analyses

TABLE 2

PREPARATION OF MAGNETIC CONCENTRATE

Unmilled Fly Ash

	2		4		6	
Magnetic Setting	Yield	S G	Yield	S G	Yield	SG
Unmilled Fly Ash						
bulk	20	3.48	47	3.43	58	3.49
270-0 mesh	37	3.89	57	3.87	65	3.78
270-325	16	3.97	44	3.85	55	3.76
325-0	12	3.83	64	3.96	61	3.76
milled fly ash						
14 hours	4	3.91	19	3.90	28	3.87

TABLE 3

PREPARATION OF MAGNETIC CONCENTRATE

FROM MILLED ASH

(maximum magnetic intensity)

Hour Milling	Grain Size % -325 mesh	Yield Magnetic Concentrate	Specific Gravity
2	95	47	3.74
4	97	57	3.75
8	100	50	3.74
24	100	42	3.79
48	100	32	3.74

Rewashing of 3.7 SG magnetic concentrate at reduced magnetic intensity gave a product of SG 3.9 (±20% yield).

TABLE 4

RELATIONSHIP BETWEEN IRON CONTENT

AND SPECIFIC GRAVITY

Size	Sample Type	% Fe_2O_3	SG
+ 100	bulk	20.31	1.75
	bulk	50.2	2.94
270-325	bulk	52.5	3.28
-325	bulk	54.9	3.30
-270	mag conc	65.6	3.52
-270	bulk	65.4	3.57
-270	mag. conc.	69.1	3.78
270-325	mag. conc.	71.9	3.64
-325	mag. conc.	72.2	3.96
270-325	mag. conc.	74.3	3.97

Correlation co-efficient 0.98

straight line fit $y = 1.07 + 0.06X$